Parabolic wave packets for time propagation of atomic hydrogen in an electric field of short laser pulses

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We propose parabolic wave packets (PWP) as a basis to solve the time-dependent Schrödinger equation (TDSE) for atomic hydrogen in a laser radiation field. Within the framework of the time-dependent variational principle (TDVP) [1], the TDSE is transformed into a set of first-order differential equations for the parameters of the PWP.

Thanks to the asymptotic properties of the basis functions, which are Sturmian basis functions of parabolic coordinates [2], the ionization amplitude is expressed in closed form in terms of the PWP parameters. The robustness of the method is first validated with a test model with analytical solution, and then applied to the ionization process of atomic hydrogen in half- and few-cycle laser pulses.

The use of parabolic coordinates, suited to the axial symmetry of the linear polarization, makes the expansion numerically efficient. The main purpose of our work is to analyze the capabilities of the TDVP formulated for PWP. The method is tested by comparing with results obtained by other methods. For example, Fig. 1 shows our results for the laser impulse case [3, 4] with $\omega = 0.3$ a.u. and $I = 10^{15}$ W/cm^2.

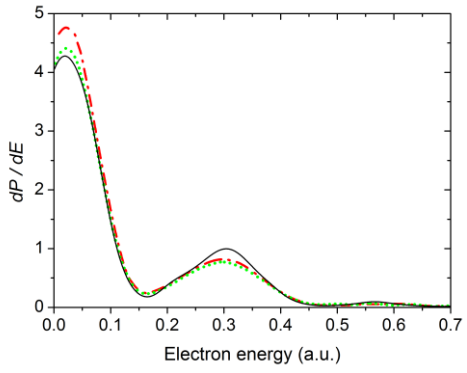

Figure 1. Photoelectron spectrum of atomic hydrogen after its irradiation with the four-cycle pulse. Solid curve: this work for the time step $\Delta t = 0.002$; dotted curve: results from [3]; dash-dotted curve: results from [4].

In turn, Fig. 2 demonstrates the behavior of the calculated ionization spectrum with decreasing the time step.

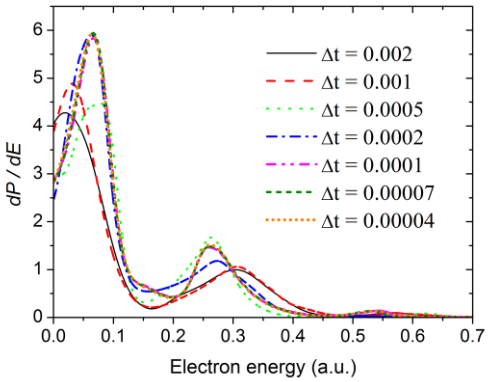

Figure 2. Convergence behavior of the photoelectron spectrum as the time step Δt decreases.

As can be seen from the figure, the final result differs markedly from the initial behavior presented in Fig. 1. The time-dependent basis functions appear to be quite flexible, so that $N = 54$ basis functions are already enough to perform such a study.

It should be added that within the framework of the method, there are not explicit restrictions on the size of the spatial region in which the solution is sought.

References

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